JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1993, 60, 571-585 NUMBER 3 (NOVEMBER)

CONDITIONAL DISCRIMINATION IN MENTALLY RETARDED SUBJECTS: PROGRAMMING ACQUISITION AND LEARNING SET

KATHRYN J. SAUNDERS AND JOSEPH E. SPRADLIN

UNIVERSITY OF KANSAS

In Experiment 1, 3 subjects with retardation were exposed to two visual-visual arbitrary matching-to-sample problems each day. One conditional discrimination was presented under trial-and-error conditions, and the other was presented under a component training procedure. The latter began by establishing the comparison discrimination and its rapid reversal. The successive discrimination between the sample stimuli was established through differential naming. Then, sample naming was maintained in conditional discrimination sessions in which the same sample was presented in blocks of consecutive trials. Block size was decreased across sessions until sample presentation was randomized as in trial-and-error training (but with naming maintained). Two subjects initially learned only with component training. The performance of the 3rd subject was inconsistent across conditional discriminations. One of the successful subjects ultimately learned rapidly and consistently with trial-and-error procedures. Experiment 2 sought to demonstrate learning set in the other 2 subjects. Elements of the component training procedure were withdrawn over successive conditional discriminations. Ultimately, 1 subject nearly always learned under trial-and-error conditions, and the other learned under trial-and-error conditions combined with differential sample naming.

Key words: conditional discrimination, matching to sample, learning set, button press, mentally retarded subjects

---

Persons with mental retardation often have great difficulty acquiring arbitrary matching to sample, a form of conditional discrimination (McIlvane, Dube, Kledaras, Iennaco, & Stoddard, 1990; Romski, Sevcik, & Pate, 1988), even though they may readily demonstrate identity matching (K. Saunders & Spradlin, 1989, 1990). We have previously suggested that these difficulties can be due to deficits in prerequisite component skills. Two of these components are the necessary simple discriminations: a successive discrimination between the sample stimuli and a simultaneous discrimination between the comparison stimuli. Although these simple discriminations are necessary to arbitrary matching, establishing them does not always result in sample control of comparison selection (K. Saunders & Spradlin, 1989). A third training component is to present the same sample in blocks of consecutive trials. Initially, blocks contain many trials, and high accuracy can be maintained because the S+ and S− functions of the comparison stimuli do not often change. The size of the blocks is reduced across sessions, gradually increasing the frequency of changes in the discriminative functions of the comparison stimuli. Used in isolation, the blocked-trial procedure may not result in acquisition of arbitrary matching. Combining the blocked-trial procedure with a differential sample response requirement (maintaining the sample discrimination) has resulted in sample control of comparison selection in 3 of 3 subjects (K. Saunders & Spradlin, 1989, 1990).

In our previous studies, the order and duration of training components were chosen for analytic purposes. Thus, subjects were exposed to trial-and-error procedures (i.e., the terminal task with differential reinforcement), or to parts of the component training procedure that were ineffective in isolation, before all skill components were trained. These features allowed a large number of errors and probably prolonged training initially. The present study was the first attempt to construct an instructional program composed of the previously studied training components. As such, the procedures were designed to establish prerequisite skills before exposure to the terminal

This work was supported by NICHD Grant 1-PO1HD18955 to the Schiefelbusch Institute for Life Span Studies, University of Kansas. We thank Dean Williams, Pamela Cress, William McIlvane, and an anonymous reviewer for helpful comments on the manuscript, Cindy Jackson and Colleen Eisenbart for laboratory assistance, Tony Grady for help with the figures, and Pat White for editorial assistance. We appreciate the support of Parsons State Hospital and Training Center. Address for correspondence: Parsons Research Center, P.O. Box 738, Parsons, Kansas 67357.

task. The two component simple discriminations were established first; the simultaneous comparison discrimination was trained before the successive sample discrimination because successive discriminations may be more difficult (e.g., Carter & Eckerman, 1975). Rapid reversal of the comparison discrimination was established in preparation for the rapid reversals needed to maintain high accuracy with blocked trials. Finally, the blocked-trial procedure was presented with maintenance of differential sample naming (used to establish the sample discrimination). Unlike in our previous studies, larger block sizes were reinstated following a single session with less than 75% accuracy. Acquisition of the terminal task with few errors would suggest that the procedures established relevant prerequisite skills (Baer, 1982; Skinner, 1968).

Another goal was to replicate systematically an earlier study that showed a learning-set outcome for arbitrary matching (K. Saunders & Spradlin, 1990). We use the term *learning-set outcome* to label the empirical observation of more rapid acquisition over successive new conditional discriminations. These procedures allowed ongoing assessment of learning without component training (i.e., under trial-and-error procedures). For each component training session presented, a session with a second conditional discrimination under trial-and-error procedures was presented on the same day. We expected that subjects would initially learn with component training but would not learn in an equal number of sessions with trial-and-error procedures. We also expected that subjects would eventually learn with trial-and-error procedures in fewer sessions than the component training procedure required (14 sessions).

EXPERIMENT 1

METHOD

Subjects

Three residents of Parsons State Hospital and Training Center served as subjects. All exhibited moderate mental retardation. CM, a 24-year-old female, achieved a mental age of 6 years on both the Leiter International Performance Scale (LIPS) and the Peabody Picture Vocabulary Test (PPVT). CM had no previous laboratory experience. BC, a 16-year-old male, received an IQ score of 40 on the WISC–R and an age equivalent of 5 years 10 months on the PPVT. Several years before the present study, attempts to teach BC a simple simultaneous discrimination using a computer-presented delayed prompt technique had been unsuccessful. ST, a 32-year-old male, achieved a mental age of 5 years 3 months on the LIPS and scores of 11 years 4 months and 8 years 10 months on the PPVT. ST's laboratory history will be described below.

Apparatus

The subject sat before a box housing an Apple IIE® microcomputer, an interface device, and a DSI tray feeder. Three windows (5 cm by 5 cm), spaced 2.5 cm apart, were cut in the front wall of the box 105 cm from the floor. During sessions, the computer's monitor was positioned such that the black stimuli displayed on the green monitor screen were centered in the display windows. The stimuli were approximately 3 cm square. A spring-loaded button with a diameter of 2.5 cm was mounted under each window. To the subject's lower left was a container into which pennies were dispensed by the feeder (see Figure 1 in R. Saunders, Wachter, & Spradlin, 1988).

Preexperimental History of Subject ST

Subject ST had learned one conditional discrimination with a procedure that approximated the current one. Major differences were that training components were presented in a different order, and there were no explicit provisions for returning to an earlier training step when accuracy was low. The procedure began after 10 trial-and-error training sessions with accuracy at chance levels. The sample discrimination was established first through differential naming, then the comparison discrimination was established and reversed, and finally the blocked-trial procedure was presented with maintenance of sample naming. A baseline period of trial-and-error training, but with maintenance of sample naming, followed both sample and comparison discrimination training. ST acquired the conditional discrimination only after exposure to the blocked-trial procedure with maintenance of sample naming, corroborating earlier findings of arbitrary matching failure after the sample and comparison discriminations were established (K.

Saunders & Spradlin, 1989). In total, the training components encompassed 172 sessions (excluding interspersed baseline sessions).

Procedure

Pretraining. The 2 less experienced subjects, CM and BC, were exposed to 32-trial identity matching sessions involving 12 letter-like stimuli. Correct button presses were prompted physically on the first few trials. When a correct comparison selection first produced tones and a penny, the experimenter commented that these came when the subject pressed the correct button, that he or she should try to get as many pennies as possible, and that the subject could keep all the pennies received. Subject BC required two sessions to reach 100% accuracy. Accuracy for Subject CM averaged 62% across the first two sessions. In the third session, we prevented overly rapid responding, and accuracy reached 94%. Accuracy was 100% in two subsequent sessions with no constraints.

Overview of procedure. After pretraining, subjects were exposed to two 32-trial sessions each weekday: one under terminal (trial-and-error) conditions only and one under the component training procedure. The stimuli are shown in Figure 1. For Subject ST, the conditional discriminations in the left column were presented under component training, and those in the right column were presented under terminal conditions only. The opposite held for Subjects BC and CM. The daily order of session type was determined by a coin flip. Training continued until 100% accuracy was reached under terminal conditions on one of the conditional discriminations (for the component training procedure, terminal conditions included maintenance of sample naming).

Terminal (trial-and-error) training conditions. Each trial began with the presentation of one of the two sample stimuli in the center display window. Sample stimuli occurred equally often in a session and were presented quasirandomly, with the restriction that the same stimulus appear on no more than three consecutive trials. A press on the center button produced the two comparison stimuli in the outer windows; each comparison stimulus occurred an equal number of times in each position and was never in the same position on more than three consecutive trials. Responses on the sample button after the comparison stimuli had been presented had no consequences. Pressing the button beneath the correct comparison produced a 1-s computer-generated jingle and the delivery of a penny, removed the stimulus display, and initiated a 5-s intertrial interval (ITI). Pressing the button under the incorrect comparison produced a buzzer and initiated the ITI. Sample or comparison button presses during the ITI reset the ITI.

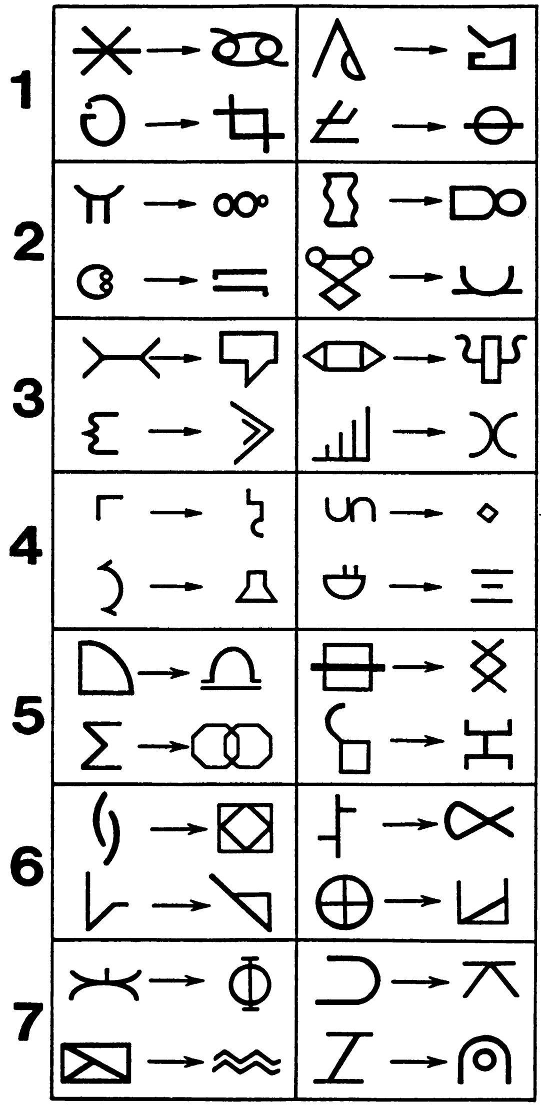

Fig. 1. The stimuli used in each pair of conditional discriminations. The arrows point from sample stimuli to the corresponding correct comparison stimuli. The stimuli presented under component training appear on the right for Subjects CM and BC and on the left for ST.

Component training procedure. Except as noted, trials operated as described above. There were three phases: (a) comparison discrimination and reversal training, (b) sample discrimination training, and (c) blocked trials with differential sample responses.

Comparison discrimination training trials began with the presentation of two comparison stimuli in the outer display windows. One comparison stimulus was designated correct for an entire session. When selection errors were confined to the first two trials of the session, the contingencies were reversed (i.e., the other comparison stimulus was designated correct) for the next session. Comparison discrimination training ended when contingency reversals were made for two consecutive sessions and selections reversed within two trials in both sessions.

Sample discrimination training involved establishing differential motor responses (oral names) to the sample stimuli. The experimenter was seated next to the subject at the apparatus. Sample stimuli were randomly presented in the center window, and the comparison keys were inoperative. Before the first sample-naming session for each conditional discrimination, subjects were told, "Today you're going to name the picture and then press the button, and I'll give you a penny when you're right. I'll help you with the names at first." To take advantage of response topographies already in the subjects' repertoires, color names were used (red, blue, orange, etc.), although the stimuli were all black. The experimenter named each stimulus the first time it appeared, and delivered a penny and praise contingent upon imitation. For the remainder of sample-naming training, pennies were delivered for naming correctly in the absence of a prompt. If the subject did not name the sample within approximately 5 s of its presentation, the experimenter said, "What's that?" After naming incorrectly (either initially or after the prompt, "What's that?"), the experimenter said the name and the subject was required to repeat it. After naming correctly, with or without a prompt, the subject was allowed to press the sample button, which removed the stimulus and presented the next trial after the ITI. Criterion was met when sample naming was 100% correct with no prompts (twice we accepted several consecutive nearly perfect sessions as criterion performance).

In the final training phase, arbitrary matching trials were presented in blocks and differential sample naming was maintained. The number of trials per block decreased over sessions. For these sessions, the experimenter sat out of the subject's view. The subject was reminded to name the sample before sessions. Prompts were presented for delayed or incorrect names, as described previously. For data-reporting purposes, however, naming correctly after the prompt "What's that?" was not an error. Occasionally, subjects completed a trial without naming (scored as a naming error). During the ITI after such trials, the subject was given a reminder such as "Remember to name before you press."

Initially, the same sample stimulus was presented on all 32 trials of a session. When comparison selection errors were confined to the first two trials, the sample stimulus was changed. After two consecutive criterion reversals, sessions containing two blocks of trials were presented (one sample for the first 16 trials and the other for the second 16 trials). When selection errors occurred only in the first two trials of each block for two sessions, sessions containing blocks of eight trials were presented. Subsequent increases in the number of reversals (decreases in block size) were made when accuracy was 100%. This criterion ensured that comparison selection was no longer solely under the control of the consequence of the previous trial (i.e., that errors did not occur on the first trial of blocks) before further reductions in block size. The number of trials per block was next decreased to four, and then sessions with irregularly sized blocks of three, four, and five trials were presented. Finally, sessions with randomized presentation of trial types were presented; these were as described for terminal or trial-and-error training conditions, except that sample naming was maintained. If accuracy fell below 75% at any point in this phase, the previous (larger) block size was reinstated until its performance criterion was met. This proviso was meant to ensure that errors occurred primarily at the beginning of trial blocks.

Results

Figures 2, 3, and 4 show the percentage of correct comparison selections under both training conditions for Subjects CM, ST, and BC, respectively. The percentage of samples named

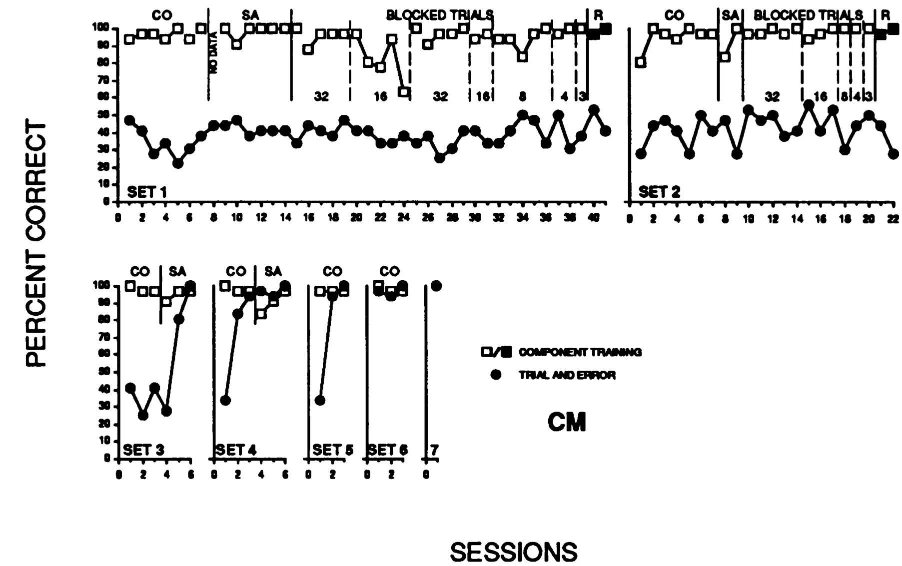

Fig. 2. For Subject CM: The percentage of correct comparison selections under all conditions except sample-naming training, for which the percentage of samples named correctly is shown. Data from trial-and-error training conditions are shown as filled circles, data from component training as open squares, and data from the terminal condition of component training as filled squares. Condition labels apply to component training: "CO" indicates comparison discrimination training, "SA" is sample discrimination training, and "R" is randomized presentation of sample stimuli (terminal training conditions). The numerals within the graph indicate the size of blocks of trials with the same sample; the label "3" refers to sessions containing a mixture of three, four, and five trial blocks.

correctly is shown only for the sample-naming training condition; accuracy rarely fell below 90% in subsequent sessions.

Subject CM

Figure 2 shows that in the first two sets of two conditional discriminations, acquisition occurred with component training in 41 and 22 sessions. Accuracy seldom fell below 90%. No trend towards acquisition was shown under trial-and-error conditions in either set. The large number of sessions in the sample discrimination training condition for the first set resulted from failure to establish responding without the prompt "What's that?"; this prompt was used for the remainder of the study for CM. In Sets 3 through 6, increasingly rapid acquisition occurred under trial-and-error conditions. Finally, the unlearned (trial-and-error) conditional discrimination from the first set was presented (labeled "7" in Figure 2); accuracy was 100% in the first session. It is unlikely that this immediate high accuracy reflected performance gains from the previous presentation of this conditional discrimination because accuracy was at chance levels at that time. More likely, it reflects one-trial learning after fortuitous selection of the correct comparison on the first trial.

Subject ST

Subject ST acquired the first two conditional discriminations with component training in 26 and 17 sessions (Figure 3). Comparison selection accuracy was below 90% only twice. Accuracy under trial-and-error conditions ranged from 25% to 65%. The third and fourth conditional discriminations were acquired under trial-and-error conditions in 13 and 6 sessions, respectively. However, across three additional conditional discrimination sets, accuracy ranged from 28% to 69% under trial-and-error conditions, and acquisition occurred virtually without error under the component training procedure.

Subject BC

Subject BC's performance differed from that of the other subjects. Figure 4 shows that he acquired the first two conditional discriminations under trial-and-error conditions, albeit slowly and with many errors. Initially, he almost always selected the same comparison stimulus. In Set 1, accuracy first exceeded 90%

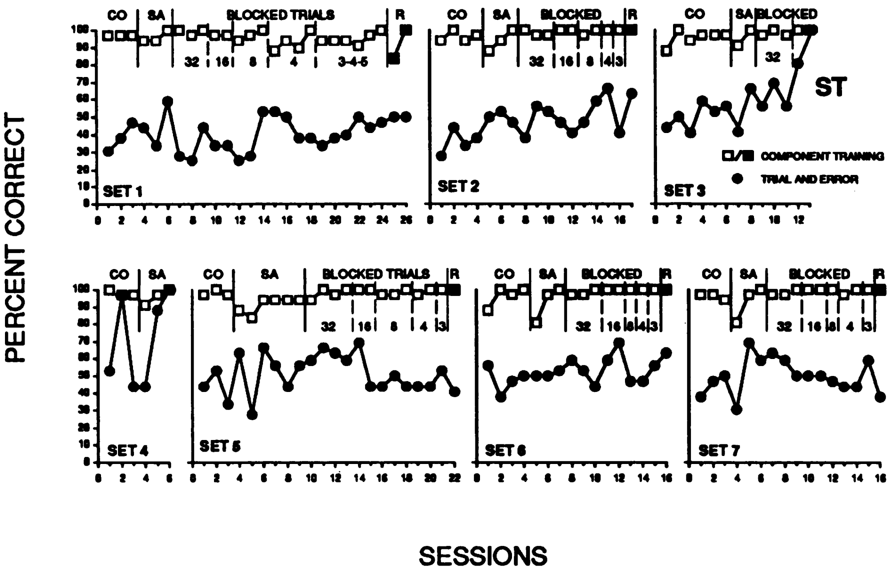

Fig. 3. Data for Subject ST (details as in Figure 2).

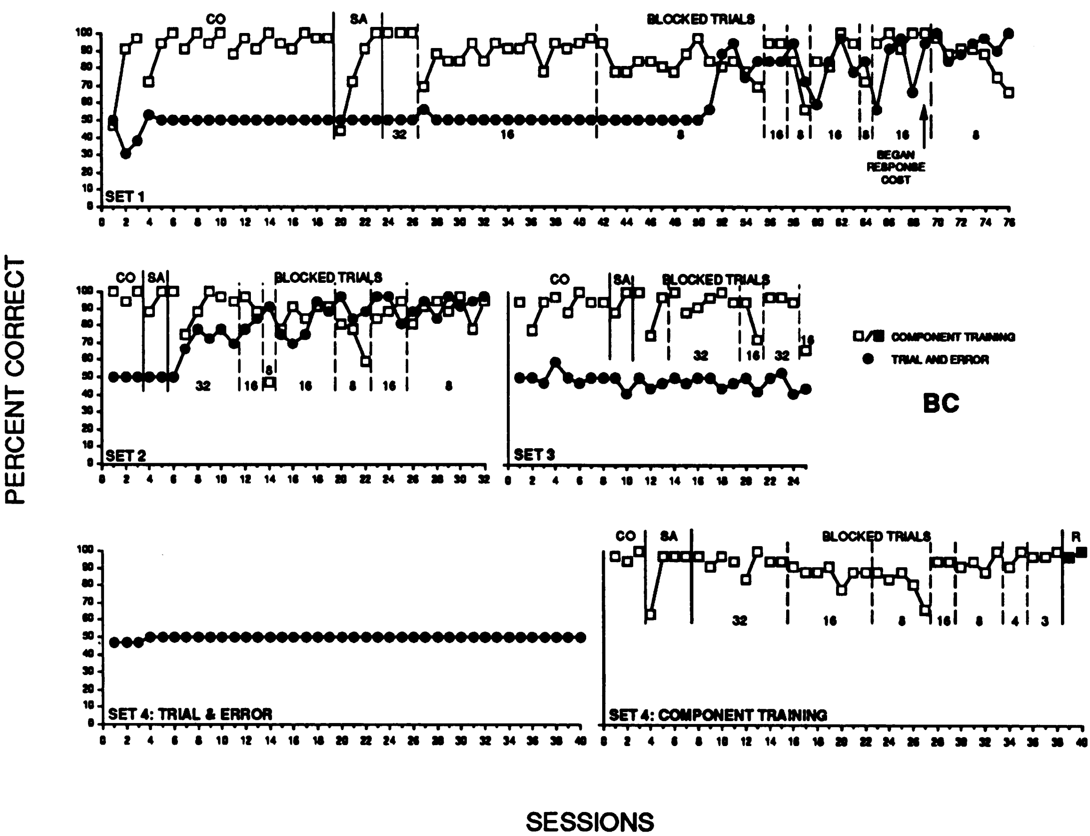

Fig. 4. Data for Subject BC (details as in Figure 2).

in Session 53 but did not reach 100% until Session 70. Because accuracy was highly variable across sessions, we made two changes in procedure. First, we implemented a response-cost procedure in both training conditions; one of five nickels was removed after each error, and BC was given the nickels remaining at the end of the session. This procedure was in effect for the remainder of Experiment 1. Second, training was continued until accuracy exceeded 90% for four consecutive sessions. This revised criterion was met on Session 76 in Set 1. In Set 2, the revised criterion was met under trial-and-error conditions in 32 sessions (100% accuracy was never achieved). Under component training, Subject BC did not advance beyond blocks of eight trials in either of the first two sets. In Set 3, performance was poor under both conditions. Under trial and error, no trend towards acquisition was shown in 25 sessions (in contrast, accuracy began increasing after the sixth session in Set 2). Under component training, accuracy fell below the "step-back" criterion twice during blocks of 16 trials; such performance decrements had not previously occurred during blocks of 16 trials.

It seemed possible that the effects of the two training procedures might be better demonstrated if each was presented independently. Thus, the next two conditional discriminations (Set 4) were presented sequentially. Across 40 trial-and-error sessions, the same comparison stimulus was selected on most trials. With component training, accuracy exceeded 80% on all but 3 of the 40 sessions required for acquisition.

Discussion

Two of 3 subjects (CM and ST) did not initially learn arbitrary matching with a trial-and-error training procedure, but they did learn with a training procedure that established component skills. One of these subjects (CM) ultimately learned consistently with trial-and-error procedures, but the other (ST) did not. The 3rd subject, BC, performed inconsistently under both procedures, but component training presented independently was most successful.

Our previous studies were designed to allow observation of the effects of individual training components. In contrast, the present procedures were designed to establish prerequisite skills before exposure to the terminal task and thus to minimize errors. For the two successful subjects, acquisition of the first conditional discrimination occurred with far fewer errors than for any of the 4 subjects studied previously (i.e., K. Saunders & Spradlin, 1989, 1990). Accuracy was above 90% in the majority of sessions for these 2 subjects, suggesting that the procedures indeed established relevant skill components. For these 2 subjects, acquisition also required many fewer sessions than for the 3 previous subjects exposed to the blocked-trials procedure with differential sample responses (1 of the 4 previous subjects was not exposed to the blocked-trial procedure). Our difficulties with Subject BC, however, suggest the need for further study.

Although the subjects initially had great difficulty acquiring visual-visual arbitrary matching under trial-and-error procedures, they exhibited other seemingly relevant skills. It is noteworthy that the subjects performed at or above the 5-year level on the Peabody Picture Vocabulary Test (PPVT). The PPVT is an auditory-visual matching task that requires the selection of pictures in the presence of spoken words. What could account for the apparent discrepancy between subjects' performances on this task and the visual-visual task studied here? One possibility is that the discrepancy is indeed only apparent. That is, the training history that was necessary for the individual arbitrary matching responses on the PPVT might have been equally extensive. It seems at least as likely, however, that the acquisition of new, spoken word-to-picture matches would have proceeded much more rapidly than visual-visual matching initially did. Most people have extensive histories with the successive discrimination of spoken words and with conditional control by spoken words. Successive discrimination of written symbols typically comes only in formal academic instruction.

Our search for a learning-set outcome in the present study systematically replicated an earlier study, but the present results differed. In the earlier study, both subjects showed consistent and increasingly rapid acquisition under trial-and-error procedures after learning two or three conditional discriminations with component training (K. Saunders & Spradlin, 1990). The present study showed consistent trial-and-error acquisition in only 1 of 3 subjects. We attributed the previous outcome simply to learning multiple conditional discriminations. However, our previous procedure permitted a gradual reduction in the number of training components over successive conditional discriminations, perhaps facilitating eventual consistent trial-and-error learning. In contrast, the present study presented either trial-and-error training or the full component training procedure—there was no intermediate amount of training. Perhaps Subjects BC and ST would eventually show consistent, rapid trial-and-error acquisition if instructional support were withdrawn gradually over several conditional discriminations.

EXPERIMENT 2

In Experiment 2, we sought to determine the minimal amount of instruction sufficient to produce reliable acquisition by Subjects ST and BC.

Method and Results

The subjects learned one conditional discrimination at a time, at first with component training. Unless noted, criteria were as for Experiment 1. When criterion accuracy (100%) was achieved under terminal conditions without accuracy falling below 88% at any point in component training, one component training step was eliminated for the next conditional discrimination. In general, comparison discrimination training and the larger block sizes were eliminated first, and sample naming was removed last. The strategy was the same for both subjects. However, slight differences in protocol (dictated by the subjects' performances) make it more efficient to present additional details of procedure and the results for each subject separately. Stimuli were similar to those used in Experiment 1.

A subgoal of Experiment 2 was to determine whether high accuracy would be maintained beyond the criterion session under terminal training conditions. Thus, after each of the last 12 conditional discriminations for Subject ST and for each of the last 22 for Subject BC, we presented at least one maintenance session at least 24 hr after criterion had been met. Accuracy was never below 90% in a maintenance session.

Subject ST

Because Subject ST was highly accurate under component training in Experiment 1, some of the criteria were adjusted at the outset. For sample naming, one session with 90% accuracy over the last 20 trials was required. Only one session with blocks of 16 trials (with no errors beyond the first two trials of a block) was required. Also, we omitted comparison discrimination reversal and Block Sizes 32 and 4 in the first conditional discrimination (CD 8).

Figure 5 shows the number of sessions at each training step for CD 8 through CD 20 (numbering is continued from Experiment 1). For example, for CD 8, ST required one session each of comparison discrimination training, sample naming, and Block Size 16. He required two sessions with blocks of eight trials, one session that mixed blocks of three, four, and five trials, and one session under terminal training conditions. The slowest acquisition was shown in the first two conditional discriminations trained after Block Size 8 was omitted (CD 10 and CD 11; note that the bar "resets" at 15 sessions for CD 10). When accuracy decreased for two consecutive sessions (as for the first three exposures to the terminal step in CD 10 and the first exposure in CD 11) or if there was no overall increase in accuracy for five sessions (as for the initial step in CD 17), the previous step was reinstated.

Four of the last five conditional discriminations (CD 16, CD 18, CD 19, and CD 20) were acquired rapidly under trial-and-error conditions. These conditional discriminations were acquired with far fewer errors than those acquired under trial-and-error conditions in Experiment 1—only two or three errors were made in the first session of each. Accuracy was similarly high in the session after sample naming was trained for CD 17, although accuracy had not exceeded 50% in the five previous sessions. It should be noted that CD 17 through CD 20 had previously been presented under trial-and-error conditions in Experiment 1, and accuracy was at chance levels for 16 to 26 sessions. Thus, the rapid acquisition of these final conditional discriminations cannot be attributed to the particular stimuli involved.

Subject BC

For Subject BC, we began by replicating the full component training procedure. However, across the first two conditional discriminations of Experiment 2 (CD 5 and CD 6), we had several difficulties that resulted in changes in procedure. We will present these manipulations in the text only. On CD 5, BC had not

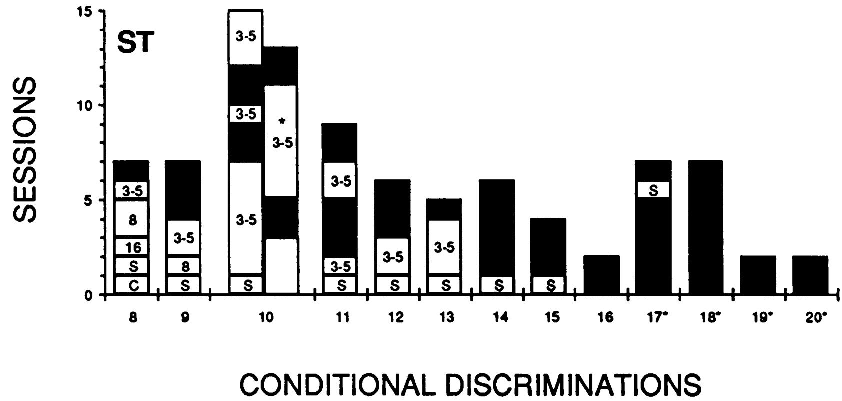

Fig. 5. Data for Subject ST. The bars show the total number of sessions required to reach 100% accuracy under terminal training conditions for each conditional discrimination in Experiment 2. Numbering of conditional discriminations is continued from Experiment 1. The demarcations within the bars show the number of sessions in each training step. Labels inside bars identify the training step (i.e., sample [S] or comparison [C] discrimination or block size). The terminal training condition is shown in black. The bar "resets" when training lasted more than 15 sessions (CD 10). The asterisk within the bar for CD 10 indicates the presentation of two sessions beyond criterion in that step. Asterisks along the x axis indicate conditional discriminations initially presented and not learned in Experiment 1.

progressed beyond blocks of 32 trials in 27 sessions, largely because performance after reversals in the Block Size 32 and comparison discrimination steps was inconsistent. BC's increasingly uncooperative behavior led to a break of almost 3 months. When sessions were resumed at BC's request, the buzzer for errors was permanently replaced by a correction procedure (trials did not advance until the correct response occurred; corrected trials resulted only in the initiation of the ITI). We made this change in hopes that it would make continued participation more likely. After reviewing sample names for the discontinued conditional discrimination, training resumed with blocks of 32 trials. A total of 20 more sessions was required, including 11 with Block Size 32.

For CD 6, the comparison discrimination reversal criterion was not met in 40 sessions. Because performance in training steps that required across-session reversals appeared to be worsening relative to the first four sets, we speculated that these seemingly simple training steps were essentially programming inattention. We thus began to withdraw instructional support by permanently eliminating comparison discrimination (and reversal) training and blocks of 32 trials. From this point, the protocol was very similar to Subject ST's, except that the accuracy criterion for the Block Size 8, Block Size 4, and Block Size 3-4-5 conditions was 90% (rather than 100%), with the provision that no more than one (for blocks of eight) or two (for smaller block sizes) errors could occur on the first trial of a block. If accuracy fell below 75% in a single session, an earlier training step was implemented.

Figure 6 shows the sequence of training steps and the number of sessions required at each step for CD 6 (excluding comparison discrimination reversal) and subsequent conditional discriminations. The conditional discriminations that required the most training, CD 8, CD 11, and CD 15, were the first attempts to eliminate Block Sizes 16, 8, and 4, respectively; these components had to be added. However, by CD 21, the blocked-trial procedure had been nearly eliminated.

We attempted to eliminate sample naming (by beginning training under terminal conditions) on CD 22, CD 24, CD 25, CD 26, and CD 28. First-session accuracy was always below 75% (ranging from 44% to 59%). In general, large increases in accuracy occurred immediately after sample naming was added (except for CD 26). When training began with sample naming (CD 21, CD 23, and CD 27), accuracy in the first trial-and-error session ranged from 91% to 97%. Thus BC nearly always learned with sample-naming training and almost never learned without it.

For CD 29 through CD 39, we changed the

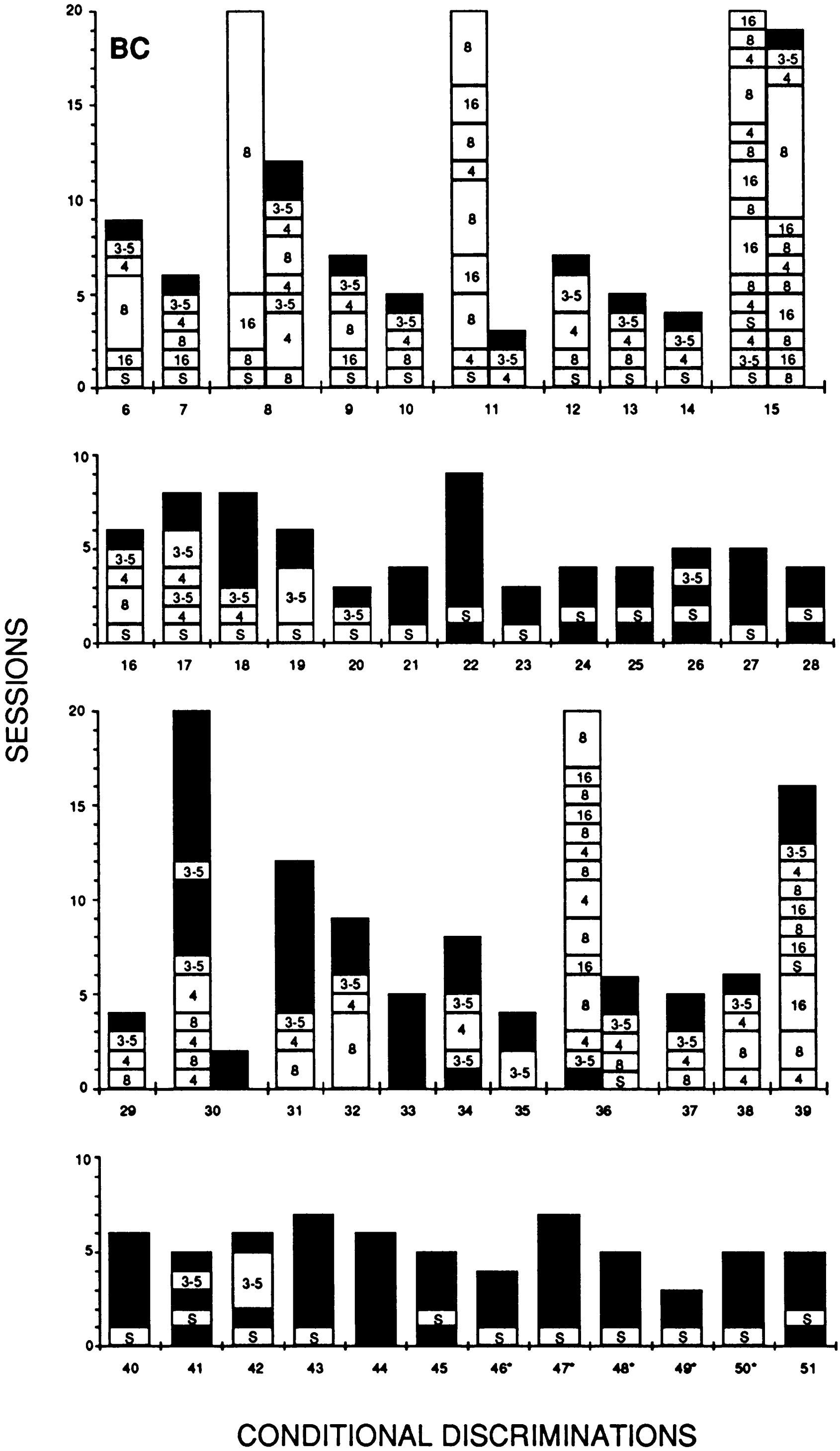

Fig. 6. Data for Subject BC (details as in Figure 5). Bars "reset" when training lasted more than 20 sessions.

strategy for withdrawing instructional support. We eliminated sample-naming training and began the training sequence with blocks of eight trials. Performance varied across conditional discriminations, with no overall progress towards eliminating instructional components. (Note that presenting terminal training conditions alone for CD 33 was a deviation from protocol because three training steps were eliminated at once.)

Beginning with CD 40, we again began training with sample naming and, in subsequent conditional discriminations, attempted to eliminate it. Although BC learned one conditional discrimination without sample naming (CD 44), low accuracy dictated the addition of sample naming for two others (initial accuracy was 66% and 59% for CD 41 and CD 45, respectively, with no improvement across trials).

Mindful that we could not study BC indefinitely, our final goal was to demonstrate stable, rapid acquisition with sample naming. Also, we again presented the conditional discriminations that we had failed to teach in Experiment 1 (CD 46 through CD 50). Accuracy was always well above 75% when sample naming was required. A final new conditional discrimination was presented with trial-and-error training first; accuracy was 62%, with no improvement across trials, in the first session.

Totaled across all opportunities in Experiment 2, accuracy exceeded 75% 10 of 11 times when trial-and-error sessions were initially presented with sample naming. When trial-and-error training began without sample naming, accuracy exceeded 75% in the first session in only 2 of 12 opportunities.

To evaluate whether naming was necessary for the *maintenance* of arbitrary matching, we conducted follow-up tests involving the final conditional discrimination (CD 51). First, we trained BC to say the same name in the presence of both samples. The name was different from the names used when the conditional discrimination was initially trained. Then, we presented one training session in which this nondifferential sample naming was required. Accuracy was 100%.

Discussion

Both subjects ultimately learned conditional discriminations far more rapidly and consistently and with less instructional support than was required initially. This learning-set outcome was probably facilitated by the gradual withdrawal of training steps. However, the study does not rule out the possibility that merely learning additional conditional discriminations with the full component training procedure would have produced the same outcome. We can say only that BC and ST did not show consistent, rapid trial-and-error acquisition as early in their laboratory histories as did CM and the 2 subjects of a previous study (K. Saunders & Spradlin, 1990).

The optimal features of the training-reduction procedures have yet to be determined. Subject BC's increasing difficulties with across-session reversals, which we discontinued, and his relative success when more frequent reversals were required (cf. Holland, 1958) suggest that the Block Size 32 and comparison discrimination steps should be withdrawn as soon as reversal performance warrants. (Indeed, perhaps reversals should never be that infrequent, especially when the sample is present.)

Subject BC showed a learning-set outcome for some components of arbitrary matching, but he seldom acquired the successive discrimination between the sample stimuli without a required differential sample response (naming). Once established, however, the sample discrimination could be maintained indirectly by the contingencies in effect for comparison selection (i.e., when differential naming was prevented). This outcome also indicates that the differential sample responses did not themselves control comparison selection, as they can for pigeons (e.g., Urcuioli, 1985).

The differential sample responses may also be called differential observing responses. Matching-to-sample procedures typically require a response to the sample stimuli prior to the presentation of the comparison stimuli. However, the usual nondifferential observing response requires only that the subject discriminate the presence versus absence of a stimulus in the sample position. It does not ensure the discrimination of the sample stimuli from each other.

Our use of sample naming as a differential sample response raises the issue of whether naming plays a role beyond that of establishing the successive discrimination between the sample stimuli. We have previously suggested that it need not, noting that studies involving differential *motor* responses to the samples have also shown enhanced acquisition in human (K. Saunders & Spradlin, 1989; Sidman et al., 1982) and nonhuman subjects (Cohen, Looney, Brady, & Aucella, 1976; Sidman et al., 1982). We used naming for convenience, assuming that it would be established rapidly. For further discussion of the role of naming in conditional discrimination and stimulus equivalence, see K. Saunders and Spradlin (1990, p. 249) and K. Saunders (1989).

GENERAL DISCUSSION

All 3 subjects initially showed extreme difficulty acquiring arbitrary matching to sample. All eventually learned numerous conditional discriminations with a procedure that established component skills in separate training steps. All showed a learning-set outcome. For 2 subjects, rapid learning under trial-and-error procedures did not occur until training steps were withdrawn over successive conditional discriminations.

Greater initial training efficiency would likely be possible if the training program specified the number of consecutive correct trials before the next reversal (sample change) on an ongoing basis rather than specifying a block size that is fixed over a 32-trial session. The fewer the number of errors after a reversal, the fewer the number of consecutive correct trials required before the next reversal (and vice versa). Also, block size should probably decrease only one or two trials at a time rather than in the large, abrupt changes used here. The exact parameters have yet to be worked out. However, it seems important that reversals not become too frequent until postreversal errors no longer occur (providing evidence of sample control). We have required near-perfect accuracy beginning with blocks of eight trials. Such procedures might allow more rapid acquisition by highly accurate subjects (like ST and CM) and promote higher overall accuracy in subjects (like BC) whose accuracy in the present version of the training procedure is lower. It may have been detrimental to BC's performance that within-session lapses in accuracy did not postpone the next sample change.

The literature now contains two promising new procedures for establishing arbitrary matching to sample in subjects with mental retardation—ours, and a procedure reported by Zygmont, Lazar, Dube, and McIlvane (1992). Both procedures establish the same skill components but in different orders. The Zygmont et al. "sample-shaping" procedure begins with identity matching to sample. If identity matching is a generalized skill, its components include the simultaneous discrimination of the stimuli involved in each trial and sample control of comparison selection. Generalized simultaneous identity matching does not require a successive discrimination between the sample stimuli (although it does not preclude one). Under the sample-shaping procedure, the sample stimuli gradually change in form until they are different from the comparison stimuli. Thus, in gradually transferring sample control from an identical to a nonidentical sample, this procedure may also establish the successive discrimination between the sample stimuli.

The function of errors differs in the two procedures. The sample-shaping procedure is potentially truly errorless. In contrast, early in the blocked-trial procedure, errors are expected on at least the first trial of a block of trials with the same sample. These errors usually produce a rapid change in comparison selection, an outcome presumably made more probable by prior comparison discrimination reversal training. Information-processing and hypothesis-theory accounts of simple discrimination learning set (see Medin, 1977; Schrier, 1984) suggest that stimulus selections and their consequences come to serve as cues for responses on subsequent trials. In the blocked-trial procedure, such conditional control of comparison selection precedes conditional control by the sample. Over trials, control of comparison selection is transferred to the sample stimulus, eliminating errors when the sample changes. It may be that, as an intermediate step, a change in sample stimulus merely controls an errorless simple discrimination reversal (i.e., initially, errorless reversals may not indicate specific sample–comparison relations; see Riopelle & Copelan, 1954).

Errors can be detrimental when they represent undesired sources of stimulus control that are inadvertently maintained by the reinforcement contingencies. In the reversal or blocked-trial procedures, the potential for the intermittent reinforcement of specific unprogrammed forms of stimulus control may be diminished. Errors that occur after a reversal involve the selection of the comparison that was correct before the change. These selections never produce reinforcement. After a history of reversals, our subjects usually reversed selections within one or two trials (although Subject BC's later difficulties with across-session reversals are a noteworthy exception). One might assume that errors are less detrimental if they play a role in the conditional control of subsequent responses that meet the reinforcement contingencies. Holland (1965) and Sidman and Stoddard (1967) note that it is not the elimination of errors per se that makes learning "easier," it is the programming of prerequisites.

From the standpoint of application, the continued development of both sample shaping and the component training procedure is warranted. It should be noted, however, that both procedures require certain prerequisite skills. Sample shaping requires identity matching. The component training procedure relies on fairly rapid development of simple discrimination reversal through trial-and-error procedures, but it may allow the study of arbitrary matching in individuals who do not demonstrate generalized identity matching. The types of stimuli used in the matching task also will influence the choice of procedure. For sample shaping, the sample initially must be identical to its "matching" comparison. In its current form, the procedure is efficient for establishing visual–visual matching involving two-dimensional stimuli. The component training procedure may be somewhat more flexible with regard to stimuli. It adapts in a straightforward fashion to auditory–visual matching, picture-to-object matching, and even identity matching. Moreover, it does not require the preparation of a graded series of sample stimuli. However, the component training procedure is less flexible than sample shaping in that it becomes unwieldy as the number of choices increases. A final consideration: It may be difficult to program learning set with the sample-shaping procedure. It remains to be seen, however, how often this will be necessary.

It is currently unknown whether the likelihood of a learning-set outcome is influenced by the procedures used to establish initial arbitrary matching performances. In general, instructional procedures have focused on the acquisition of individual discriminations. Moreover, the basic research literature contains little information on engendering learning set for either simple or conditional discrimination by other than trial-and-error procedures (for exceptions with simple discrimination, see Dube, Iennaco, Rocco, Kledaras, & McIlvane, 1992; Herman & Arbeit, 1973).

What changes when a previously unsuccessful subject comes to learn rapidly with differential reinforcement (trial-and-error) procedures? Ray and Sidman (1970) noted that a stimulus–response relation, like a response, has to occur to be reinforced: "Making reinforcement contingent upon the presence of a stimulus at the time of a response is different from making reinforcement contingent on a controlling stimulus–response relation" (p. 193). The following account makes a parallel assumption for conditional discrimination. In addition, it incorporates elements of earlier accounts of simple discrimination learning set, such as Harlow's (1959) error factor theory and the "win-stay, lose-shift" of hypothesis theory (for reviews, see Medin, 1977; Schrier, 1984).

Early in our subjects' experimental histories, it is likely that very few comparison selections were part of a controlling relation involving the sample stimulus. Other controlling relations occurred far more frequently, and these sometimes adventitiously met the programmed contingencies (e.g., selecting the same comparison or the same position on all trials). Thus the target controlling relations were not selected and maintained by the contingencies. Following this conceptual analysis, the behavior of a (hypothetical) perfectly trained organism has changed in two ways. First, across conditional discriminations, competing sources of control are eliminated. For example, comparison stimulus or position biases are no longer present upon initial exposure to training trials for new matching problems. Second, no more than four controlling stimulus–response relations are present initially. When the A1 sample is presented, either the A1-B1 or the A1-B2 controlling relation occurs. When the A2 sample is presented, either the A2-B2 or the A2-B1 controlling relation occurs. Few instances of reinforcement are required to increase the probability of the specified correct relations, and few instances of extinction or punishment are required to decrease the probability of the incorrect relations. If training begins with the presentation of each of the two trial types under differential reinforcement, one might expect 50% accuracy across those first two trials and rapidly increasing accuracy thereafter.

Sometimes subjects show even more rapid acquisition, with correct selections probable beginning with the second trial of new conditional discriminations, even if the second trial differs from the first (Subject CM showed some evidence of this at the end of Experiment 1). Such high second-trial accuracy can be accounted for by exclusion and/or S− control (e.g., McIlvane et al., 1987) that develops after a trial of differential reinforcement. For example, if B1 is selected in the presence of the A1 sample on the first trial and the A2 sample is presented on the second trial, B2 may be selected by exclusion.

Conditional discrimination learning set may have relevance to studies of more complex processes that require baseline performances of arbitrary matching. For example, generalized rapid conditional discrimination acquisition might affect the likelihood of the subsequent demonstration of equivalence relations. Thus, studies attempting to compare equivalence performances across different subject populations (e.g., across species or levels of mental retardation) might begin with an attempt to establish equally rapid conditional discrimination acquisition in all subjects. Perhaps the most important attribute of the procedure studied here is that it enabled difficult-to-teach subjects ultimately to learn conditional discriminations rapidly with minimal instruction.

REFERENCES

Baer, D. M. (1982). The imposition of structure on behavior and the demolition of behavioral structures. In H. E. Howe, Jr. & D. J. Bernstein (Eds.), *Nebraska symposium on motivation: Response structure and organization* (pp. 217-254). Lincoln: University of Nebraska Press.

Carter, D. E., & Eckerman, D. A. (1975). Symbolic matching by pigeons: Rate of learning complex discriminations predicted from simple discriminations. *Science*, **187**, 662-664.

Cohen, L. R., Looney, T. A., Brady, J. H., & Aucella, A. F. (1976). Differential sample response schedules in the acquisition of conditional discriminations by pigeons. *Journal of the Experimental Analysis of Behavior*, **26**, 301-314.

Dube, W. V., Iennaco, F. M., Rocco, F. J., Kledaras, J. B., & McIlvane, W. J. (1992). Microcomputer-based programmed instruction in identity matching to sample for persons with severe disabilities. *Journal of Behavioral Education*, **2**, 29-51.

Harlow, H. F. (1959). Learning set and error factor theory. In S. Koch (Ed.), *Psychology: A study of a science* (Vol. 2, pp. 492-537). New York: McGraw-Hill.

Herman, L. M., & Arbeit, W. R. (1973). Stimulus control and auditory discrimination learning sets in the bottlenose dolphin. *Journal of the Experimental Analysis of Behavior*, **19**, 379-394.

Holland, J. G. (1958). Human vigilance. *Science*, **128**, 61-67.

Holland, J. G. (1965). Research on programming variables. In R. Glaser (Ed.), *Teaching machines and programmed learning: II. Data and directions* (pp. 66-117). Washington, DC: National Education Association of the United States.

McIlvane, W. J., Dube, W. V., Kledaras, J. B., Iennaco, F. M., & Stoddard, L. T. (1990). Teaching relational discrimination to individuals with mental retardation: Some problems and possible solutions. *American Journal on Mental Retardation*, **95**, 283-296.

McIlvane, W. J., Kledaras, J. B., Munson, L. C., King, K. A. J., deRose, J. C., & Stoddard, L. T. (1987). Controlling relations in conditional discrimination and matching by exclusion. *Journal of the Experimental Analysis of Behavior*, **48**, 187-208.

Medin, D. L. (1977). Information processing and discrimination learning set. In A. M. Schrier (Ed.), *Behavioral primatology: Advances in research and theory* (Vol. 1, pp. 33-69). Hillsdale, NJ: Erlbaum.

Ray, B. A., & Sidman, M. (1970). Reinforcement schedules and stimulus control. In W. N. Schoenfeld (Ed.), *The theory of reinforcement schedules* (pp. 187-214). New York: Appleton-Century-Crofts.

Riopelle, A. J., & Copelan, E. L. (1954). Discrimination reversal to a sign. *Journal of Experimental Psychology*, **48**, 143-145.

Romski, M. A., Sevcik, R. A., & Pate, J. L. (1988). Establishment of symbolic communication in persons with severe retardation. *Journal of Speech and Hearing Disorders*, **53**, 94-107.

Saunders, K. J. (1989). Naming in conditional discrimination and stimulus equivalence. *Journal of the Experimental Analysis of Behavior*, **51**, 379-384.

Saunders, K. J., & Spradlin, J. E. (1989). Conditional discrimination in mentally retarded adults: The effect of training the component simple discriminations. *Journal of the Experimental Analysis of Behavior*, **52**, 1-12.

Saunders, K. J., & Spradlin, J. E. (1990). Conditional discrimination in mentally retarded adults: The development of generalized skills. *Journal of the Experimental Analysis of Behavior*, **54**, 239-250.

Saunders, R. R., Wachter, J., & Spradlin, J. E. (1988). Establishing auditory stimulus control over an eight-member equivalence class via conditional discrimination procedures. *Journal of the Experimental Analysis of Behavior*, **49**, 95-115.

Schrier, A. M. (1984). Learning how to learn: The significance and current status of learning set formation. *Primates*, **25**, 95-102.

Sidman, M., Rauzin, R., Lazar, R., Cunningham, S., Tailby, W., & Carrigan, P. (1982). A search for symmetry in the conditional discriminations of rhesus monkeys, baboons, and children. *Journal of the Experimental Analysis of Behavior,* **37,** 23–44.

Sidman, M., & Stoddard, L. T. (1967). The effectiveness of fading in programming a simultaneous form discrimination for retarded children. *Journal of the Experimental Analysis of Behavior,* **10,** 3–15.

Skinner, B. F. (1968). *The technology of teaching.* New York: Appleton-Century-Crofts.

Urcuioli, P. J. (1985). On the role of differential sample behaviors in matching-to-sample. *Journal of Experimental Psychology: Animal Behavior Processes,* **11,** 502–519.

Zygmont, D. M., Lazar, R. M., Dube, W. V., & McIlvane, W. J. (1992). Teaching arbitrary matching via sample stimulus-control shaping to young children and mentally retarded individuals: A methodological note. *Journal of the Experimental Analysis of Behavior,* **57,** 109–117.

Received August 10, 1992
Final acceptance June 25, 1993